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Presence of Finger Extension and Shoulder Abduction Within 72 Hours After Stroke Predicts Functional Recovery

Early Prediction of Functional Outcome After Stroke: The EPOS Cohort Study

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Background and Purpose**—**The aim of the present study was to determine if outcome in terms of upper limb function at 6 months after stroke can be predicted in hospital stroke units using clinical parameters measured within 72 hours after stroke. In addition, the effect of the timing of assessment after stroke on the accuracy of prediction was investigated by measurements on days 5 and 9.

Methods**—**Candidate determinants were measured in 188 stroke patients within 72 hours and at 5 and 9 days after stroke. Logistic regression analysis was used for model development to predict upper limb function at 6 months measured with the action research arm test (ARAT).

Results**—**Patients with an upper limb motor deficit who exhibit some voluntary extension of the fingers and some abduction of the hemiplegic shoulder on day 2 have a probability of 0.98 to regain some dexterity at 6 months, whereas the probability was 0.25 for those without this voluntary motor activity. Sixty percent of patients with some early finger extension achieved full recovery at 6 months in terms of action research arm test score. Retesting the model on days 5 and 9 resulted in a gradual decline in probability from 0.25 to 0.14 for those without voluntary motor activity of shoulder abduction and finger extension, whereas the probability remained 0.98 for those with this motor activity.

Conclusions**—**Based on 2 simple bedside tests, finger extension and shoulder abduction, functional recovery of the hemiplegic arm at 6 months can be predicted early in a hospital stroke unit within 72 hours after stroke onset. **(*Stroke*. 2010;41:745-750.)**

Key Words: prognosis ■ stroke ■ upper extremity

Although prospective epidemiological studies are lacking, findings of a number of prospective cohort studies suggest that 33% to 66%[1,2] of stroke patients with a paretic upper limb do not show any recovery of upper limb function 6 months after stroke. Depending on the outcome measures used, 5% to 20% achieve full functional recovery of upper limb function at 6 months.[3]

Early prediction of final functional outcome for the paretic upper limb is paramount for stroke management, including discharge policies at hospital stroke units. Considering that most patients are discharged to rehabilitation centers or nursing homes within the first week after stroke to reduce health care costs, discharge planning should start within the first days after stroke.[4] Moreover, guidelines for rehabilitation management recommend starting the treatment of stroke patients as early as possible.[5] Prospective cohort studies have shown that early return of finger extension,[6,7] shoulder shrug and abduction,[8] and active range of motion[9] are important prognostic determinants of the outcome for the paretic upper limb 6 months after stroke. Additionally, results from a recent cohort study with repeated measurements in time suggest that the outcome in terms of regaining dexterity at 6 months is largely defined within the first 4 weeks after stroke.[10] Unfortunately, most previous studies did not investigate the

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time dependency of clinical determinants in relation to spontaneous neurological recovery in the very early stages of recovery.[11,12]

To improve early stroke management, an answer is required to the question whether accurate prediction of the final outcome in terms of upper limb function can be achieved within the first days after stroke at the hospital stroke unit. Therefore, the first aim of the present study was to determine if outcome in terms of upper limb function at 6 months can be predicted within 72 hours after stroke onset. The second aim was to explore the biological relationship of the proposed clinical predictors with spontaneous neurological recovery by means of investigating the effect of the moment of assessment on the accuracy of prediction by assessing on days 5 and 9 after stroke.

Materials and Methods

The Early Prediction of Functional Outcome after Stroke (EPOS) study is a prospective cohort study whose design involves intensive repeated measurements within the first 2 weeks after stroke onset. Over a period of 24 months, 188 stroke patients were recruited from 9 acute hospital stroke units in the Netherlands. All determinants were measured within 72 hours after stroke and were reassessed on days 5 and 9. Final outcome was defined at 6 months after stroke using the action research arm test (ARAT).[13–15] Measurements were performed by trained assessors working as physical therapists or occupational therapists in the stroke units of the participating centers (including several affiliated nursing homes). All assessors were familiar with the test battery. In addition, a 1-day training course was given and the assessors were tested for interobserver reliability. All patients received treatment according to the Dutch rehabilitation guidelines, which are in agreement with current international rehabilitation guidelines.[5,16] The research proposal was approved by ethics committees of all participating hospitals and all affiliated rehabilitation centers and nursing homes approved local feasibility.

Subjects

Stroke was defined according to the World Health Organization criteria.[17] Type and localization of stroke were determined using CT or MRI scans and clinical features according to the Bamford classification.[18] Patients meeting the following admission criteria were included: (1) a first-ever ischemic anterior circulation stroke; (2) a monoparesis or hemiparesis within the first 72 hours after stroke onset; (3) no disabling medical history (ie, a premorbid Barthel Index score $\geq$19); (4) at least 18 years of age; (5) no severe deficits in communication, memory, or understanding that impede proper measurement performance; and (6) signed informed consent.

Dependent Variable

The outcome in terms of hemiplegic arm function was assessed with the ARAT. This 1-dimensional hierarchical scale consists of 19 functional tasks that are divided into 4 domains, i.e, grasp, grip, pinch, and gross movement, with a maximum total score of 57 points. The clinimetric properties of the ARAT are excellent.[13,14] All ARAT measurements were performed in a standardized manner according to van der Lee et al.[14]

For the purpose of logistic regression analysis, ARAT scores were dichotomized into "1" for those who regained some dexterity ($\geq$10 points on ARAT) and "0" for those who did not regain any dexterity ($<$10 points on ARAT).[10] A cut-off score of $\geq$10 points was chosen because a score of $\leq$9 points mainly reflects gross arm movements, whereas a score $>$9 points always represents some hand function.[10,14,15]

Independent Variables

On the basis of existing literature[7–9] and a previous cohort study of predicting upper limb function early after stroke,[10] the following candidate determinants were selected for the development of a prediction model: (1) gender; (2) age; (3) hemisphere of stroke; (4) type of stroke (Bamford classification)[18]; (5) days between stroke and first assessment; (6) recombinant tissue plasminogen activator; (7) comorbidity (Cumulative Illness Rating Scale[19]); (8) visual inattention (National Institutes of Health Stroke Scale[20] item 11); (9) hemianopia (National Institutes of Health Stroke Scale item 3); (10) deviation conjugee (National Institutes of Health Stroke Scale item 2); (11) sensory loss (National Institutes of Health Stroke Scale item 8); (12) Activities of Daily Living score (Barthel Index total score[21]); (13) urinary incontinence (Barthel Index item 2); (14) severity and extent of paresis of the arm and leg according to the upper and lower extremity parts of the Motricity Index[22] and the Fugl-Meyer assessment[23]; and (15) sitting balance (trunk control test,[24] item 3).

Data Analysis

The possible association between the return of some dexterity on ARAT (ie, $\geq$10 points) at 6 months and the candidate determinants (independent variables) within 72 hours was investigated using bivariate logistic regression analysis and calculating odds ratios and their 95% confidence intervals (CI). Ordinal or ratio scaled determinants were preferably dichotomized on clinical grounds; in the other cases, the optimal cut-off point for each determinant was determined with the help of a receiver-operating characteristic curve. The optimal dichotomization was estimated separately for each candidate determinant on the basis of sensitivity/1 − specificity and maximum area under the curve for each cut-off score. Based on the bivariate logistic regression analysis, significant determinants ($P \leq 0.10$) were selected for the subsequent development of a multivariate logistic model predicting within 72 hours whether some (ie, ARAT $\geq$10 points) or no (ie, ARAT $<$10) dexterity will return after 6 months. Collinearity between the determinants included was defined if their correlation coefficient was $\geq$0.7. Subsequently, the determinant with the lowest odds ratio was excluded from multivariate modeling. Because of the large number of variables relative to the number of patients involved, the maximum likelihood estimation of parameters in the multivariate model was conditional on the basis of a forward stepwise approach. Entry and removal criteria with $P=0.05$ and $P=0.10$, respectively, were used. The multivariate logistic model thus derived was used to calculate probabilities for developing some dexterity at 6 months using the following equation:

$$P=1/(1+(\exp^{[-(B_0+B_1X_1+B_2X_2+B_3X_3\ldots-B_nX_n)]}))$$

A 2-way contingency table was used to calculate sensitivity, specificity, negative predictive value, and positive predictive value, including their 95% CI. The same analyses were repeated for assessments at 5 and 9 days after stroke. All analyses used 2-tailed tests and were conducted using SPSS version 15.

Results

One hundred eighty-eight stroke patients were recruited for the EPOS study in 24 months. Nineteen patients died during follow-up, 2 patients refused assessment at 6 months, 3 patients were excluded after admission because of recurrent stroke, 2 were unable to undergo the assessments, and 3 were lost to follow-up. Finally, 3 patients were excluded because of incomplete data on the baseline Fugl-Meyer assessments. Table 1 presents the main characteristics of the remaining 156 patients. The mean (SD) moments when the candidate determinants were measured were 2.26 (1.28), 5.48 (1.40), and 9.02 (1.81) days after stroke. The median ARAT score was 1.5 points on day 2. At 6 months, some dexterity (ARAT $\geq$10 points) in the paretic arm was found in 70.5% of the subjects, whereas 34% showed a maximum score of 57 points on the ARAT.

Table 1. Patient Characteristics Within 72 Hours After Stroke

Patient Characteristics	Total
N	156
Gender, F/M	87/69
Mean age (SD), yr	66.47 (14.43)
Hemisphere of stroke, L/R	69/87
rt-PA, no/yes	117/39
Mean BMI (SD)	26 (4.62)
Mean time interval between stroke (SD) and	
First assessment, d, mean (SD)	2.26 (1.28)
Second assessment, d	5.48 (1.40)
Third assessment, d	9.02 (1.81)
Type of stroke (Bamford)	
LACI	79
PACI	50
TACI	27
NIHSS*	7 (4–14)
Cognitive disturbance	
Inattention, no/yes	93/63
Disorientation, no/yes	119/37
Impairments of vision	
Hemianopia, no/yes	114/42
Deviation conjugee, no/yes	122/34
Sensory loss, no/yes	63/93
TCT (0–100)*	74 (37–100)
MI arm (0–100)*	39 (0–76)
MI leg (0–100)*	53 (23–83)
FM arm (0–66)*	21 (4–56)
FM leg (0–34)*	21 (9–29)
FAC (0–5)*	1 (0–3)
ARAT total score (0–57)*	1.5 (0–41)
BI total score (0–20)*	8 (3–14)
BI urinary incontinence, no/yes (no=2; yes≤1)	76/79

BI indicates Barthel Index; BMI, body mass index; F, female; FAC, Functional Ambulation Categories Score; FM, Fugl-Meyer; L, left; LACI, lacunar anterior cerebral infarction; M, male; MI, Motricity Index; NIHSS, National Institutes of Health Stroke Scale; PACI, partial anterior cerebral infarction; R, right; rt-PA, recombinant tissue plasminogen activator; SD, standard deviation; TACI, total anterior cerebral infarction; TCT, trunk control test.

*Median values (interquartile ranges).

Bivariate Associations Between Dependent and Independent Variables

Table 2 shows odds ratios and their 95% CI as determined by bivariate logistic regression analysis within 72 hours after stroke. Eleven candidate determinants were significantly related to the return of some dexterity at 6 months after stroke. The highest odds ratios were found for finger extension according to the Fugl-Meyer hand score, using an optimal cut-off of 1 point, followed by shoulder abduction according to the Motricity Index arm score, with an optimal cut-off of 9 points. Collinearity diagnostics showed a significant correlation coefficient of 0.75 between "shoulder elevation" and "shoulder abduction." As a consequence, shoulder abduction, which showed a higher association with ARAT, was included in the multivariate modeling.

Table 2. Candidate Determinants Measured Within 72 Hours Associated With the Return of Some Dexterity at 6 Months After Stroke as Determined by Logistic Regression Coefficients

	N=156		
Determinant	OR	95% CI	*P*
Gender, M/F	1.58	0.79–3.15	0.198
Age (0<70; 1≥70)	1.13	0.57–2.25	0.726
Hemisphere of stroke, L/R	0.44	0.21–0.91	0.027
Bamford (0, TACI/PACI; 1, LACI)	10.56	4.31–25.85	<0.001
Days between stroke and first assessment	0.98	0.75–1.28	0.877
rt-PA (no/yes)	1.73	0.81–3.73	0.158
CIRS total score (0≥1; 1=0)	1.96	0.96–3.98	0.063
Visual inattention (0≥1; 1=0)	7.91	3.62–17.32	<0.001
Hemianopia (0≥1; 1=0)	7.63	3.47–16.80	<0.001
Deviation conjugee (0≥1; 1=0)	9.00	3.84–21.05	<0.001
Sensory loss (0≥1; 1=0)	9.15	3.36–24.89	<0.001
Urinary incontinence (0<1; 1≥1)	6.41	2.81–14.59	<0.001
MI shoulder abduction (0=0; 1≥9)	32.57	12.64–83.92	<0.001
MI leg (0<25; 1≥5)[16]	15.35	6.47–36.49	<0.001
FM shoulder elevation (0<1; 1≥1)	22.80	9.39–55.37	<0.001
FM finger extension (FM, 0<1; 1≥1)	58.67	13.83–257.17	<0.001
Sitting balance (TCT item 3, 0<25; 1=25)[16]	20.67	8.44–50.62	<0.001

The values between the brackets represent the cut-off scores.

BAMFORD: TACI, total anterior cerebral infarction; PACI, partial anterior cerebral infarction; LACI, lacunar anterior cerebral infarction; rt-PA, recombinant tissue plasminogen activator; CIRS, Cumulative Illness Rating Scale; MI, Motricity Index; FM, Fugl-Meyer.

Multivariate Modeling

Table 3 shows the multivariate logistic regression models for days 2, 5, and 9 after stroke. The probability to achieve some dexterity 6 months after the stroke for those patients who showed some voluntary finger extension and some shoulder abduction on day 2 was estimated at 0.98. The probability for those without voluntary motor activity of these determinants was estimated at 0.25. Two-way contingency table analysis showed a sensitivity of 0.89 (95% CI, 0.85–0.92), a specificity of 0.83 (95% CI, 0.72–0.90), a positive predictive value of 0.93 (95% CI, 0.88–0.96), and a negative predictive value of 0.76 (95% CI, 0.67–0.83). Sixty percent of the patients with some voluntary finger extension (N=82) reached the maximum ARAT score of 57 points, whereas 48% of the patients who were able to abduct the paretic shoulder (N=104) reached the maximum ARAT score. Thirty-four percent of all 156 patients reached a score of 57 points on the ARAT.

Retesting the multivariate model for days 5 and 9 showed that the probability remained 0.98 for those patients able to extend their fingers and abduct their shoulders, and it declined to 0.14 for those who did not satisfy either of these criteria. Two-way contingency table analysis showed a sen-

Table 3. Probabilities of Achieving Some Dexterity at 6 Months After Stroke

FE	SA	True Negatives, N	False Negatives, N	False Positives, N	True Positives, N	P
ARAT ≥10 at 6 Months						
Model for day 2, $P=1/(1+1*(EXP(-1.119+2.807*FE+2.149*SA)))$						
FM FE ≥1	MI SA ≥9					
+	+	38	12	8	98	0.98
+	−					0.89
−	+					0.71
−	−					0.25
Model for day 5, $P=1/(1+1*(EXP(-1.874+3.070*FE+3.075*SA)))$						
FM FE ≥1	MI SA ≥9					
+	+	38	6	8	104	0.98
+	−					0.78
−	+					0.78
−	−					0.14
Model for day 9, $P=1/(1+1*(EXP(-1.815+3.224*FE+2.449*SA)))$						
FM FE ≥1	MI SA ≥9					
+	+	38	6	8	104	0.98
+	−					0.80
−	+					0.65
−	−					0.14

N=156.

FE indicates finger extension; SA, shoulder abduction; FM, Fugl-Meyer; MI, Motricity Index.

sitivity of 0.95 (95% CI, 0.91–0.97), specificity of 0.83 (95% CI, 0.74–0.89), positive predictive value of 0.93 (95% CI, 0.89–0.95), and negative predictive value 0.86 (95% CI, 0.77–0.93) for both days.

Discussion

The present study is the first prospective cohort study to our knowledge to show that accurate prediction of upper limb function is possible within 72 hours after stroke by using 2 simple clinical tests, ie, finger extension and shoulder abduction. Those patients with some finger extension and shoulder abduction on day 2 after stroke onset had a 98% probability of achieving some dexterity at 6 months. In contrast, patients who did not show this voluntary motor control had a probability of 25%. It is also remarkable that 60% of the patients with some finger extension within 72 hours had regained full recovery of upper limb function according to the ARAT at 6 months. This finding confirms the substantial predictive value of finger extension as a positive sign for a favorable outcome for the upper paretic limb in the acute phase after stroke. Retesting the model on days 5 and 9 showed that the probability of regaining dexterity remained 98% for those with some finger extension and shoulder abduction, whereas the probability decreased from 25% to 14% for those without this voluntary control.

Although the present study did focus on the early time window of stroke recovery, our findings build on results of previous prospective studies that started beyond the first week after stroke.[7–10] For example, Smania et al[7] showed in a sample of 48 stroke patients that active finger extension at day 7 after stroke is an early valid indicator of a favorable outcome in terms of upper limb function measured with the nine-hole peg test, the Fugl-Meyer arm, and the Motricity Index arm. Katrak et al[8] reported that initial shoulder abduction, measured an average of 11 days after stroke, is an early predictor of good hand function at 1 and 2 months after stroke. Our results validate the value of assessing shoulder abduction and finger extension as early favorable indicators for some return of dexterity at 6 months after stroke.

The preservation of voluntary finger extension may reflect the need for some fibers of the corticospinal tract system in the affected hemisphere to remain intact to control distal arm and hand muscles,[25,26] assuming that the hand lacks bilateral innervation from both hemispheres.[27] To date, transcranial magnetic stimulation[25,28] and diffusion tensor imaging[25,29] studies further underpin this hypothesis. For example, van Kuijk et al[28] showed that in patients with an initial paralysis of the upper limb, the presence or absence of a motor-evoked potential in the abductor digiti minimi measured with transcranial magnetic stimulation at the end of the first week after stroke is highly predictive for final outcome of dexterity at 6 months. However, the presence or absence of a motor-evoked potential in the abductor digiti minimi has similar predictive values when compared to clinical assessment alone.[28] The present study suggests that transcranial magnetic stimulation measurements should investigate the predictive validity of motor-evoked potentials of finger extensors rather than finger flexors or the abductor digiti minimi alone.[30]

The presence of shoulder abduction as a determinant for upper limb function may reflect the intralimb neural coupling between proximal and distal segments in motor control. As early as 1916, Souques[31] observed that elevation of the affected arm frequently caused the paralyzed finger to extend. A recent study has shown that distal elbow joint control is dependent on shoulder abduction.[32] Obviously, the strength of shoulder abduction affects the elbow-flexion torque and, with that, the reaching range of motion (work area) in patients with stroke.[32]

With respect to the second aim of the present study, to explore the biological relationship of the proposed clinical determinants with spontaneous neurological recovery, the presented findings show that the probability of regaining some dexterity after 6 months decreased from 25% to 14% in the first 9 days for those without finger extension and shoulder abduction. This may reflect the gradual decline of uncertainty as a result of time-dependent spontaneous processes, such as decrease of cerebral shock or diaschisis.[33,34] In contrast, for those patients with some finger extension and shoulder abduction, the probability of regaining dexterity remained 98%. This latter finding suggests that the viability of the corticospinal tract system is almost entirely defined within the first days after stroke in terms of achieving dexterity at 6 months. However, it is important to note that these findings do not suggest that no changes in upper limb function occur beyond 9 days, but rather that the final outcome of dexterity is almost fully defined within this critical time window in this cohort with mild to moderate impairments. To improve our understanding of mechanisms that may underlie recovery, future prospective studies should longitudinally combine clinical and noninvasive neurophysiologic assessments such as transcranial magnetic stimulation and functional MRI in an intensive, early, repeated-measurement design after stroke.[30]

For clinical practice, the findings of the present study might improve early stroke management decisions like discharge and multidisciplinary intervention planning at (sub)acute stroke units. As a consequence, subsequent multidisciplinary rehabilitation services may be optimized in line with the probability for regaining some dexterity, particularly acknowledging that many evidence-based therapies for the upper paretic limb, including Constrained Induced Movement Therapy and may require some return of voluntary wrist and finger extension.[6,35] The findings of a recent study by Smania et al[36] strengthen this suggestion by also showing the predictive validity of finger extension and shoulder abduction at day 7 for daily life autonomy.

In interpreting the findings of the present study, some limitations should be noted. In accordance with the stroke guidelines,[5] we included only medically stable patients with first-ever ischemic strokes in 1 of the hemispheres. As a consequence, patients with a mild-to-moderate stroke who were able to communicate and understand were included in the present study. This might limit the generalization of the present findings to other patients with problems like dysphasia, confusion, or reduced consciousness. However, having an early prognosis is most relevant for an appropriate discharge treatment policy from a hospital stroke unit for the cohort we selected.

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Disclosure

None.

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